ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICES WITH INSULATED DRIVER ELECTRODES

Inventors:
Igor Y. Botvinnik
Andrew J. Parker
Charles E. Taylor

Priority Claim

[0001] The present application claims priority under 35 U.S.C. 119(e) to U.S. Provisional Patent Application No. 60/500,437, filed September 5, 2003, entitled "Electro-Kinetic Air Transporter and Conditioner Devices with Insulated Driver Electrodes."

Cross-Reference to Related Art

[0002] The present invention is related to the following patent applications and patent, each of which is incorporated herein by reference: U.S. Patent Application No. 10/074,207, filed February 12, 2002, entitled "Electro-Kinetic Air Transporter-Conditioner Devices with Interstitial Electrode"; U.S. Patent Application No. 10/074,827, filed February 12, 2002, "Electro-Kinetic Air Transporter-Conditioner with Non-Equidistant Collector Electrodes"; and U.S. Patent No. 6,176,977, entitled "Electro-Kinetic Air Transporter-Conditioner".

Field of the Invention:

[0003] The present invention relates generally to devices that electro-kinetically transport and/or condition air.

Background of the Invention:

[0004] It is known in the art to produce an airflow using electro-kinetic techniques, by which electrical power is converted into a flow of air without mechanically moving components. One such system was described in U.S. Patent No. 4,789,801 to Lee (1988), depicted herein in simplified form as FIG. 1. System 100 includes a first array 110 of emitter electrodes 112 that are spaced-apart symmetrically from a second array 120 of collector electrodes 122. The positive terminal of a high voltage pulse generator 140 that outputs a train of high voltage pulses (e.g., 0 to perhaps + 5 KV) is coupled to the first array 110, and the negative pulse generator terminal is coupled to the second array 120 in this example.

[0005] The high voltage pulses ionize the air between arrays 110 and 120, and create an airflow 150 from the first array 110 toward the second array 120, without requiring any moving parts. Particulate matter 160 in the air is entrained within the airflow 150 and also moves towards the collector electrodes 122. Some of the particulate matter is electrostatically attracted to the surfaces of the collector electrodes 122, where it remains, thus conditioning the flow of air exiting system 100. Further, the corona discharge produced between the electrode arrays can release ozone into the ambient environment, which can eliminate odors that are entrained in the airflow, but is generally undesirable in excess quantities.

[0006] In a further embodiment of Lee shown herein as FIG. 2, a third array 230 includes passive collector electrodes 232 that are positioned midway between each pair of collector electrodes 122. According to Lee, these passive collector electrodes 232, which were described as being grounded, increase precipitation efficiency. However, because the grounded passive collector electrodes 232 (also referred to hereafter as driver electrodes) are located close to adjacent negatively charged

collector electrodes 122, undesirable arcing (also known as breakdown or sparking) will occur between collector electrodes 122 and driver electrodes 232 if the potential difference therebetween is too high, or if a carbon path is produced between an electrode 122 and an electrode 232 (e.g., due to a moth or other insect that got stuck between an electrode 122 and electrode 232). It is also noted that driver electrodes are sometimes referred to as interstitial electrodes because they are situated between other (i.e., collector) electrodes.

[0007] Increasing the voltage difference between the emitter electrodes 112 and the collector electrodes 122 is one way to further increase particle collecting efficiency and air flow rate. However, the extent that the voltage difference can be increased is limited because arcing will eventually occur between the collector electrodes 122 and the driver electrodes 232. Such arcing will typically decrease the collecting efficiency of the system, as well as produce an unpleasant odor.

[0008] Accordingly, there is a desire to improve upon existing electro-kinetic techniques. More specifically there is a desire to increase particle collecting efficiency and airflow rate, and to reduce arcing between electrodes.

<u>Summary of the Present Invention:</u>

[0009] Embodiments of the present invention are related to electro-kinetic air transporter-conditioner systems and methods. In accordance with an embodiment of the present invention, a system includes at least one emitter electrode and at least one collector electrode that is downstream from the emitter electrode. An insulated driver electrode is located adjacent the collector electrode. A high voltage source provides a voltage potential to at least one of the emitter electrode and the collector electrode to thereby provide a potential different therebetween. The insulated driver electrode(s) may or may

not be at a same voltage potential as the emitter electrode, but should be at a different voltage potential than the collector electrode.

[0010] The insulation (i.e., dielectric material) on the driver electrodes allows the voltage potential to be increased between the driver and collector electrodes, to a voltage potential that would otherwise cause arcing if the insulation were not present. This increased voltage potential increases particle collection efficiency. Additionally, the insulation will reduce, and likely prevent, any arcing from occurring if a carbon path is formed between the collector and driver electrodes, e.g., due to an insect getting caught therebetween.

[0011] In accordance with an embodiment of the present invention, the emitter electrode(s) and the insulated driver electrode(s) are grounded, while the high voltage source is used to provide a high voltage potential to the collector electrode(s) (e.g., -16KV). This is a relatively easy embodiment to implement since the high voltage source need only provide one polarity.

[0012] In accordance with an embodiment of the present invention, the emitter electrode(s) is at a first voltage potential, the collector electrode(s) is at a second voltage potential different than the first voltage potential, and the insulated driver electrode is at a third voltage potential different than the first and second voltage potentials. One of the first, second and third voltage potentials can be ground, but need not be. Other variations, such as the emitter and driver electrodes being at the same potential (ground or otherwise) are within the scope of the invention.

[0013] In accordance with an embodiment of the present invention, the emitter electrode(s) may be generally equidistant from the upstream ends of the closest pair of collector electrodes. In other embodiments, certain emitter electrodes are moved outward to thereby adjust the electric fields

produced between the emitter electrodes and the collector electrodes, and thus establish a non-equidistant relationship.

[0014] In accordance with an embodiment of the present invention, an the upstream end of each insulated driver electrode is set back a distance from the upstream end of the collector electrode(s).

[0015] Each insulated driver electrode includes an underlying electrically conductive electrode that is covered with, for example, a dielectric material. The dielectric material can be, for example, a heat shrink tubing material or an insulating varnish type material. In accordance with an embodiment of the present invention, the dielectric material is coated with an ozone reducing catalyst. In accordance with another embodiment of the present invention, the dielectric material includes or is an ozone reducing catalyst.

[0016] The embodiments as describe above have some or all of the advantages of increasing the particle collection efficiency, increasing the rate and/or volume of airflow, reducing arcing, and/or reducing the amount of ozone generated. Further, ions generated using many of the embodiments of the present invention will be more of the negative variety as opposed to the positive variety.

[0017] In accordance with an embodiment of the present invention, an insulated driver electrode includes generally flat elongated sides that are generally parallel with the adjacent collector electrode(s). Alternatively, an insulated driver electrode can include one, or preferably a row of, insulated wire-shaped electrodes.

[0018] Other features and advantages of the invention will appear from the following description in which the preferred embodiments have been set forth in detail, in conjunction with the accompanying drawings and claims.

Brief Description of the Figures:

[0019] FIG. 1 illustrates schematically, a prior art electro-kinetic conditioner system.

[0020] FIG. 2 illustrates schematically, a further prior art electro-kinetic conditioner system.

[0021] FIG. 3 illustrates schematically, an electro-kinetic conditioner system according to an embodiment of the present invention.

[0022] FIG. 4 illustrates schematically, an electro-kinetic conditioner system according to another embodiment of the present invention.

[0023] FIG. 5 illustrates schematically, an electro-kinetic conditioner system according to a further embodiment of the present invention.

[0024] FIG. 6 illustrates exemplary electrostatic field lines produced using embodiments of the present invention.

[0025] FIG. 7 illustrates the relative distances between various electrodes of the electro-kinetic conditioner systems of the present invention.

[0026] FIG. 8 illustrates schematically, an electro-kinetic conditioner system according to a further embodiment of the present invention where additional emitter electrodes are used.

[0027] FIG. 9 illustrates schematically, an electro-kinetic conditioner system according to an embodiment of the present invention, where the location of the emitter electrodes are adjusted to change the electric field distribution.

[0028] FIG. 10 illustrates schematically, an electro-kinetic conditioner system according to an embodiment of the present invention, where the location of the collector electrodes are adjusted to change the electric field distribution.

[0029] FIG. 11 illustrates the use of a ozone reducing catalyst over the insulation of the insulating driver electrodes of the present invention.

[0030] FIG. 12 illustrates schematically, an electro-kinetic conditioner system according to an embodiment of the present invention, where the insulated driver electrodes are wire-like.

[0031] FIGS. 13A and 13B illustrates an electro-kinetic conditioner system, according to an embodiment of the present invention, wherein the collector electrodes are U-shaped.

[0032] FIG. 14 illustrates a perspective view of an electro-kinetic conditioner unit, according to an embodiment of the present invention.

[0033] FIG. 15 is block diagram showing an exemplary implementation of a high voltage source that can be used with embodiments of the present invention.

[0034] FIG. 16 is graph that is useful for showing how embodiments of the present invention can be used to increase particle collection efficiency.

Detailed Description

[0035] FIG. 3 illustrates schematically, an electro-kinetic conditioner system 300 according to an embodiment of the present invention. The system includes a first array 310 (i.e., emitter array) of emitter electrodes 312, a second array 320 (i.e. ,collector array) of collector electrodes 322 and a third array 330 of insulated driver electrodes 330. In this embodiment, the first array 310 is shown as being connected to a positive terminal of a high voltage source 340, and the second array 320 is shown as being connected to a negative terminal of the high voltage source 340. The third array 330 of insulated driver electrodes 332 are shown as being grounded.

[0036] Each insulated driver electrode 332 includes an electrically conductive electrode 334 that is covered by a dielectric material 336. In accordance with an embodiment of the present invention, the dielectric material 336 is heat shrink tubing. During manufacture, the heat shrink tubing is placed over the driver electrodes 334 and then heated, which causes the tubing to shrink to the shape of the driver electrodes 334. An exemplary heat shrinkable tubing is type FP-301 flexible polyolefin tubing available from 3M of St. Paul, Minnesota.

[0037] In accordance with another embodiment of the present invention, the dielectric material 336 is an insulating varnish, lacquer or resin. For example, a varnish, after being applied to the surface of the driver electrodes 334, dries and forms an insulating coat or film a few mil (thousands of an inch) in thickness covering the electrodes 334. The dielectric strength of the varnish or lacquer can be, for example, above 1000 V/mil (one thousands of an inch). Such insulating varnishes, lacquer and resins are commercially available from various sources, such as from John C. Dolph Company of Monmouth Junction, New Jersey, and Ranbar Electrical Materials Inc. of Manor, Pennsylvania.

[0038] Other possible dielectric materials that can be used to insulate the driver electrodes include ceramic or porcelain enamel or fiberglass. These are just a few examples of dielectric materials that can be used to insulate the driver electrodes 334. It is within the spirit and scope of the present invention that other insulating dielectric materials can be used to insulate the driver electrodes.

[0039] During operation of system 300, the high voltage source 340 positively charges the emitter electrodes 312 (of the first array 310) and negatively charges the collector electrodes 322 (of the second array 320). For example, the voltage on the emitter electrodes 312 can be +6KV, while the voltage on the collector electrodes 322 can be –10KV, resulting in a 16KV potential difference between the emitter electrodes 312 and collector electrodes 322. This potential difference will produces a high intensity electric field the is highly concentrated around the emitter electrodes 312. More specifically, a corona discharge takes place from the emitter electrodes 312 to the collector electrodes 322, producing positively charged ions. Particles (e.g., dust particles) in the vicinity of the emitter electrodes 312 are positively charged by the ions. The positively charged ions are repelled by the positively charged emitter electrodes 312, and are attracted to and deposited on the negatively charged collector electrodes 322.

[0040] Further electric fields are produced between the insulates driver electrodes 332 and collector electrodes 322, which further push the positively charged particles toward the collector electrodes 322. Generally, the greater this electric field between the driver electrodes and collector electrodes, the greater the particle collection efficiency. In the prior art, the extent that this voltage difference (and thus, the electric field) could be increased was limited because arcing would occur between the collector electrodes and un-insulated driver electrodes beyond a certain voltage potential difference. However, with the present invention, the insulation 336 covering electrodes 334 significantly

increases the voltage potential difference that can be obtained between the collector electrodes 322 and the driver electrodes 332 without arcing. The increased potential difference results in an increase electric field, which significantly increases particle collecting efficiency. By analogy, the insulation 336 works much the same way as a dielectric material works in a parallel plate capacitor. That is, even though a parallel plate capacitor can be created with only an air gap between a pair of differently charged conductive plates, the electric field can be significantly increased by placing a dielectric material between the plates.

[0041] As will be described in further detail below, a system such as system 300 will likely be included within a freestanding housing the is meant to be placed in a room (e.g., near a corner of a room) to thereby clean the air in the room, circulate the air in the room, and increase the concentration of negative ions in the room. Such a housing will likely include a side having one or more inlet vents and an opposing side having one or more outlet vents, with the side having the outlet vent(s) intended not to face any wall. Thus, the side of the housing having the inlet vent(s) will often be placed close to wall. Accordingly, it is likely that the positively charged emitter electrodes 312 will be in close proximity to the floor and/or wall(s) of a room. The floor or walls of a room can generally be thought of as having a grounded voltage potential. Accordingly, with system 300 there will be a potential difference, and thus electric field, between the positively charge emitter electrodes 312 and any nearby floor and/or wall(s), or even furniture, in a room. The effect of this is that a portion of the positively charged ions (and positively charge particles) produced in the vicinity of the emitter electrodes 312 may travel backward, i.e., in a direction opposite or away from the collector electrodes 322. This can cause the undesirable effects of reducing cleaning efficiency, increasing positive ions in a room, and causing particles to stick to the floor and/or walls

in the room. Many of the following embodiments of the present invention overcome these just mentioned deficiencies.

[0042] FIG. 4 illustrates schematically, an electro-kinetic conditioner system 400 according to another embodiment of the present invention. The arrangement of system 400 is similar to that of system 300 (and thus, is numbered in the same manner), except that the emitter electrodes 312 are grounded in system 400, rather than being connected to the positive output terminal of a high voltage source 340. The collector electrodes 322 are still negatively charged. Further, the insulated driver electrodes 332 are still grounded.

[0043] The electro-kinetic conditioner system 400 operates in a similar manner to system 300. More specifically, during operation of system 400, the high voltage source 340 negatively charges the collector electrodes 322 (of the collector array 320). For example, the voltage on the collector electrodes 322 can be –16KV, resulting in a 16KV potential difference between the grounded emitter electrodes 312 and the collector electrodes 322. This potential difference will produces a high intensity electric field that is highly concentrated around the emitter electrodes 312. More specifically, a corona discharge takes place from the emitter electrodes 312 to the collector electrodes 322, producing positive ions. This causes particles (e.g., dust particles) in the vicinity of the emitter electrodes 312 become positively charged relative to the collector electrodes 322. The particles are attracted to and deposited on the negatively charged collector electrodes 322. Additionally, there will be a 16KV potential difference between the insulated driver electrodes 332 and the collector electrodes 322, which pushes particles toward the collector electrodes 322. Advantageously, in this embodiment the emitter electrodes 312 will be generally at the same potential as the floor and walls

of a room within which system 400 is placed. This will significantly reduce, and possibly prevent, any charged particles from flowing backward, i.e., away from the collector electrodes.

[0044] Another advantage of system 400 is that it requires only a single polarity voltage supply (e.g., voltage source 340 need only provide a –16KV potential, without requiring any positive supply potential). Thus, system 400 is relatively simple to design, build and manufacture, making it a very cost effective system.

[0045] FIG. 5 illustrates schematically, an electro-kinetic conditioner system 500 according to another embodiment of the present invention. The arrangement of system 500 is similar to that of system 400 (and thus, is numbered in the same manner), except that the insulated driver electrodes 332 are connected to the positive output terminal of the high voltage source 340, rather than being grounded as in system 300. The collector electrodes 322 are still negatively charged. Further, the emitter electrodes 312 are still grounded. Positively charging the insulated drivers 332 can be used to increase the potential difference between the insulated driver array 330 and the collector array 320, thereby increasing the particle collecting efficiency. For example, the voltage on the collector electrodes 322 can be –16KV, while the voltage on the insulated drivers 332 can be +5KV, resulting in a 21KV potential difference between the collector electrodes 322 and the insulated driver electrodes 332 , while keeping the voltage potential difference between the emitter electrodes 312 and collector electrodes 322 at 16KV.

[0046] The electro-kinetic conditioner system 500 operates in a similar manner to system 400. Advantageously, as in system 400, in this embodiment the emitter electrodes 312 will be generally at the same potential as the floor and walls of a room within which system 500 is placed, which will significantly reduce, and possibly prevent, any charged particles from flowing backward, i.e., away

from the collector electrodes 322. While system 500 will be quite effective, it will require a slightly more complex voltage source 340, since voltage source 340 must provide both a positive and negative voltage potential.

[0047] In addition to those described above, there are other voltage potential variations that can be used to drive an electro-kinetic system including an insulated driver electrode(s) 332. To summarize, in system 300 shown in FIG. 3, the emitter electrodes 312 were positive, the collector electrodes 322 were negative, and the insulated driver electrodes 332 were grounded. In system 400 shown in FIG. 4, the emitter electrodes 312 and the insulated driver electrodes 332 were grounded, and the collector electrodes 322 were negative. It would also be possible to modify the system 400 to make the insulated driver electrodes 332 slightly negative (e.g., -1KV) so long as the collector electrodes 322 were significantly more negative (e.g., -16KV). In system 400, the emitter electrodes 312 were grounded, the collector electrodes 322 were negative, and the insulated driver electrodes 332 were positive. System 400 can be modified, for example, by making the emitter electrodes 312 slightly negative or slightly positive. Other variations are also possible while still being within the spirit as scope of the present invention. For example, the emitter electrodes 312 and insulated driver electrodes 332 can be grounded, while the collector electrodes 322 have a high negative voltage potential or a high positive voltage potential. It is also possible that the instead of grounding certain portions of the electrode arrangement, the entire arrangement can float (e.g., the insulated driver electrodes 332 and the emitter electrodes 312 can be at a floating voltage potential, with the collector electrodes 322 offset from the floating voltage potential).

[0048] An important feature according to an embodiment of the present invention is that, if desired, the voltage potential of the emitter electrodes 312 and insulated driver electrodes 332 can be

independently adjusted. This allows for corona current adjustment (produced by the electric field between the emitter electrodes 312 and collector electrodes 322) to be performed independently of the adjustments to the electric fields between the insulated driver electrodes 332 and collector electrodes 322. More specifically, this allows the voltage potential between the emitter electrodes 312 and collector electrodes 322 to be kept below arcing levels, while still being able to independently increase the voltage potential between the insulated driver electrodes 332 and collector electrodes 322 to a higher voltage potential difference than would be possible between the emitters 312 and collectors 322.

[0049] The electric fields produced between the emitter electrodes 312 and collector electrodes 322 (also referred to as the ionization regions), and the electric fields produced between the insulated driver electrodes 332 and collector electrodes 322 (also referred to as the collector regions), are show as exemplary dashed lines in FIG. 6. The ionization regions produce ions and cause air movement in a downstream direction from the emitter electrodes 312 toward the collector electrodes 322. The collector regions increase particle capture by pushing charged particles in the air flow toward the collector electrodes 322.

[0050] It is preferably that the electric fields produced between the insulated driver electrode(s) 332 and collector electrodes 322 (i.e. the collecting regions) do not interfere with the electric fields between the emitter electrode(s) 312 and the collector electrodes 322 (i.e., the ionization regions). If this were to occur, the collecting regions will reduce the intensity of the ionization regions, thereby reducing the production of ions and slowing down air movement. Accordingly, the leading ends of the driver electrodes 332 are preferably set back (i.e., downstream) from the leading ends of the collector electrodes 322 by about the same distance that the emitter electrodes 312 are from the

collector electrodes 322. This is shown in FIG. 7, where the setback distance X of an insulated driver electrodes 332 is approximately equal to the distance Z between an emitter electrode 312 and the closest collector electrodes 322. Still referring to FIG. 7, it is also desirable to have the distance Y between a pair of adjacent emitter electrodes 312 about equal to the setback distance X. However, other set back distances are within the spirit and scope of the present invention.

[0051] As explained above, the emitter electrodes 312 and insulated driver electrodes 332 may or may not be at the same voltage potential, depending on which embodiment of the present invention is practiced. When at the same voltage potential, there will be no problem of arcing occurring between the emitter electrodes 312 and insulated driver electrodes 332. Further, even when at different potentials, because the insulated driver electrodes 332 are setback as described above, the collector electrodes 322 will shield the insulated driver electrodes 332, as can be appreciated from the electric field lines shown in FIG. 6. Thus, as shown in FIG. 6, there is generally no electric field produced between the emitter electrodes 312 and the insulated driver electrodes 332. Accordingly, arcing should not occur therebetween.

[0052] Referring back to FIG. 6, it can be appreciated that the outermost surfaces of the outer collector electrodes 322a and 322d are farthest from any of the emitter electrodes 312, resulting in a lower electric field at these surfaces. This will reduce the particle collecting efficiency of the outermost surfaces of the outer collector electrodes 322a and 322d. To increase the electric field at these surfaces, and thus the particle collection efficiency, two extra emitter electrodes can be added in accordance with an embodiment of the present invention, as shown in FIG. 8. While the extra emitters will increase particle collection efficiency, they may also add to the overall size of the system, potentially increase ozone production, and increase the power consumption of the system.

[0053] An scheme for producing a more uniform airflow, is to move the outer emitter electrodes outward, as shown in FIG. 9.

[0054] Referring back to FIG. 6, it can be appreciated that the strength of the electric field generated at the leading or upstream ends of the inner most collector electrodes 322b and 322c (i.e., the ends closest to the emitter electrodes 312) will be greater than the electric field generated at the leading ends of the outer most collector electrodes 322a and 322d. This may cause a greater amount of airflow movement in the middle of collector array 320 (i.e., near collector electrode 322b and 322c), as compared to near the outer collector electrodes 322a and 322d. If a more even airflow is desired, the inner collector electrodes 322b and 322c can be moved slightly downstream, as shown in FIG. 10.

[0055] In addition to producing ions, the systems described above will also produce ozone (O_3). While limited amounts of ozone are useful for eliminating odors, concentrations of ozone beyond recommended levels are generally undesirable. In accordance with embodiments of the present invention, ozone production is reduced by coating the insulated driver electrodes 332 with an ozone reducing catalyst. Exemplary ozone reducing catalysts include manganese dioxide and activated carbon. Commercially available ozone reducing catalysts such as PremAir™ manufactured by Englehard Corporation of Iselin, New Jersey, can also be used.

[0056] Some ozone reducing catalysts, such as manganese dioxide are not electrically conductive, while others, such as activated carbon are electrically conductive. When using a catalyst that is not electrically conductive, the insulation 334 can be coated in any available manner because the catalyst will act as an additional insulator, and thus not defeat the purpose of adding the insulator 334. However, when using a catalyst that is electrically conductive, it is important that the electrically

conductive catalyst does not interfere with the benefits of insulating the driver. This will be described with reference to FIG. 11

[0057] Referring now to FIG. 11, an underlying driver electrode 334 is covered by dielectric insulation 336 to produce an insulated driver electrode 332. The underlying driver electrode 334 is shown as being connected by a wire 1102 (or other conductor) to a voltage potential (ground in this example). An ozone reducing catalyst 1104 covers most of the insulation 336. If the ozone reducing catalyst does not conduct electricity, then the ozone reducing catalyst 1104 may contact the wire or other conductor 1102 without negating the advantages provided by insulating the underlying driver electrodes 334. However, if the ozone reducing catalyst 1104 is electrically conductive, then care must be taken so that the electrically conductive ozone reducing catalyst 1104 (covering the insulation 336) does not touch the wire or other conductor 1102 that connects the underlying driver electrode 334 to a voltage potential (e.g., ground, a positive voltage, or a negative voltage). So long as an electrically conductive ozone reducing catalyst does not touch the wire 1104 that connects the driver electrode 334 to a voltage potential, then the potential of the electrically conductive ozone reducing catalyst will remain floating, thereby still allowing an increased voltage potential between insulated driver electrode 332 and adjacent collector electrodes 322. Other example of electrically conductive ozone reducing catalyst include, but are not limited to, noble metals.

[0058] In accordance with another embodiment of the present invention, if the ozone reducing catalyst is not electrically conductive, then the ozone reducing catalyst can be included in, or used as, the insulation 336. Preferably the ozone reducing catalysts should have a dielectric strength of at least 1000 V/mil (one-hundredth of an inch) in this embodiment.

[0059] The positively charged particles that travel from the regions near the emitter electrodes 312 toward the collector electrodes 322 are missing electrons. In order to clean the air, it is desirable that the particles stick to the collector electrodes 322 (which can later be cleaned). Accordingly, it is desirable that the exposed surfaces of the collector electrodes 322 are electrically conductive so that the collector electrodes 322 can give up a charge (i.e., an electron), thereby causing the particles to stick to the collector electrodes 322. Accordingly, if an ozone reducing catalyst is electrically conductive, the collector electrodes 322 can be coated with the catalyst. However, it is preferably to coat the insulated driver electrodes 332 with an ozone reducing catalyst, rather than the collector electrodes 322. This is because as particles collect on the collector electrodes 322, the surfaces of the collector electrodes 322 become covered with the particles, thereby reducing the effectiveness of the ozone reducing catalyst. The insulated driver electrodes 332, on the other hand, do not collect particles. Thus, the ozone reducing effectiveness of a catalyst coating the insulated driver electrodes 332 will not diminish due to being covered by particles.

[0060] In the previous FIGS., the insulated driver electrodes 332 have been shown as including a generally plate like electrically conductive electrode 334 covered by a dielectric insulator 336. In alternative embodiments of the present invention, the insulated driver electrodes can take other forms. For example, referring to FIG. 12, the driver electrodes can be include a wire or rod-like electrical conductor 334' covered by dielectric insulation 336'. Although a single such insulated driver electrode 332' can be used, it is preferably to use a row of such insulated drivers electrodes 332', as shown in FIG. 12. The electric field between such a row of insulated driver electrodes 332' and the collector electrodes 322 will look similar to the corresponding electric field shown in FIG. 6.

[0061] In the various electrode arrangements described herein, emitter electrode(s) 312 in the first electrode array 310 can be fabricated, for example, from tungsten. Tungsten is sufficiently robust in order to withstand cleaning, has a high melting point to retard breakdown due to ionization, and has a rough exterior surface that seems to promote efficient ionization. The emitter electrodes 312 are likely wire-shaped, and are likely manufactured from a wire or, if thicker than a typical wire, still has the general appearance of a wire or rod. Alternatively, as in known in the art, other types of ionizers, such as pin or needle shaped electrodes can be used in place of a wire. For example, an elongated saw-toothed edge can be used, with each edge functioning as a corona discharge point. A column of tapered pins or needles would function similarly. As another alternative, a plate with a sharp downstream edge can be used as an emitter electrode. These are just a few examples of the emitter electrodes that can be used with embodiments of the present invention. Further, other materials besides tungsten can be used to produce the emitter electrodes 312.

[0062] Collector electrodes 322 in the second electrode array 320 can have a highly polished exterior surface to minimize unwanted point-to-point radiation. As such, collector electrodes 322 can be fabricated, for example, from stainless steel and/or brass, among other materials. The polished surface of collector electrodes 322 also promotes ease of electrode cleaning. The collector electrodes 322 are preferably lightweight, easy to fabricate, and lend themselves to mass production. Accordingly, even though the collector electrodes can be solid, it is more practical that the collector electrodes be manufactured from sheet metal. When made from sheet metal, the sheet metal can be readily configured to define side regions and a bulbous nose region, forming a hollow, elongated "U"-shaped electrode, for example, as shown in FIG. 13A. Each "U"-shaped electrode has a nose and two trailing sides. Similarly, in embodiments including plate like insulated driver electrodes

332, the underlying driver electrodes can be made of a similar material and in a similar shape (e.g., "U" shaped) as the collector electrodes 322. FIG. 13B shows a perspective view of the electrode assembly shown in FIG. 13A. The corresponding perspective views for the electrode configurations discussed in the previous FIGS. will look similar. It is within the spirit and scope of the invention that the emitter electrodes 312 and collector electrodes 322, as well as the insulated driver electrodes 332, can have other shapes besides those specifically mentioned herein.

[0063] In the FIGS. discussed above, four collector electrodes 322 and three insulated driver electrodes 332 were shown, with either three emitter electrodes 312, or five emitter electrodes 312. These numbers of electrodes have been shown for example, and can be changed. Preferably there is at least a pair of collector electrodes with an insulated driver electrode therebetween to push charged particles toward the collector electrodes. However, it is possible to have embodiments with only one collector electrode, and one or more emitter electrodes. In such embodiments, the insulated driver electrode should be generally parallel to the collector electrode.

[0064] Preferably, there is at least one emitter electrode 312 for each pair of collector electrodes 322. In the embodiment depicted, each the emitter electrode 312 is preferably equidistant from the noses or leading edges of the two closest collector electrodes 322, as shown, for example, in FIG. 6. However, in certain embodiments, such as the one discussed with reference to FIG. 9, the location of the outermost emitter electrodes 312 may be change to alter the resulting electric fields in a desired manner. As discussed with reference to FIG. 8, adding emitter electrodes 312 may also be useful.

[0065] It may also be practical to add insulated driver electrodes an either sides of the outer collector electrodes (e.g., on either side of collector electrodes 322a and 322d shown in FIG. 8). This would

push any charged particles passing adjacent to the outer surfaces of the outer collector electrodes (e.g., 322a and 322d in FIG. 8) toward the outer surfaces of the outer collector electrodes.

[0066] In some embodiments, the number N1 of emitter electrodes 312 in the emitter array 310 can differ by one relative to the number N2 of collector electrodes 322in the collector array 320. In many of the embodiments shown, N2>N1. However, if desired, additional emitter electrodes could be added at the outer ends of array 310 such that N1>N2, e.g., five emitter electrodes 312 compared to four collector electrodes 322, as in FIG. 8.

[0067] Referring now to FIG. 14, the above described electro-kinetic air transporter-conditioner systems are likely within or include a housing 1402. The housing likely includes rear-located intake vents 1404 and front located exhaust or outlet vents 1406, and a base pedestal 1408. Preferably, the housing 1402 is free standing and/or upstandingly vertical and/or elongated. The base 1408, which may be pivotally mounted to the remainder of the housing, allows the housing 1402 to remain in a vertical position.

[0068] Internal to the transporter housing 1402 is one of the electro-kinetic transporter and conditioner systems described above. The electro-kinetic transporter and conditioner system is likely powered by an AC-DC power supply that is energizable or excitable using switch S1. Switch S1, along with the other user operated switches such as a control dial 1410, are preferably located on or near a top 1403 of the housing 1402. The whole system is self-contained in that other than ambient air, nothing is required from beyond the transporter housing 1402, except perhaps an external operating voltage, for operation of the present invention.

[0069] A user-liftable handle member 1412 is preferably affixed the collector array 320 of collector electrodes 322, which normally rests within the housing 1402. The housing 1402 also encloses the

array 310 of emitter electrodes 312 and the array 330 of insulated driver electrodes 332. In the embodiment shown, the handle member 1412 can be used to lift the collector array 310 upward causing the collector electrodes 322 to telescope out of the top of the housing 1402 and, if desired, out of the housing 1402 for cleaning, while the emitter electrode array 310 and insulated driver electrodes array 330 remain within the housing 1402. As is evident from FIG. 14, the collector array 310 can be lifted vertically out from the top 1403 of the housing along the longitudinal axis or direction of the elongated housing 1402. This arrangement with the collector electrodes 322 removable through a top portion of the housing 1402, makes it easy for a user to pull the collector electrodes 322 out for cleaning, and to return the collector electrodes 322, with the assistance of gravity, back to their resting position within the housing 1402. If desired, the emitter array 310 and/or the insulated driver array 330 may be made similarly removable.

[0070] There need be no real distinction between vents 1404 and 1406, except their location relative to the electrodes. These vents serve to ensure that an adequate flow of ambient air can be drawn into or made available to the electrodes, and that an adequate flow of ionized cleaned air moves out from housing 1402.

[0071] The above described embodiments do not specifically include a germicidal (e.g., ultra-violate) lamp. However, a germicidal lamp can be included with the above configurations. Where the insulated driver electrodes are coated with an ozone reducing catalyst, the ultra-violate radiation from such a lamp may increase the effectiveness of the catalyst. The inclusion of a germicidal lamp is shown in FIG. 15. Additional details of the inclusion of a germicidal lamp are included in U.S. Patent No. 6,544,485, entitled "Electro-Kinetic Device with Enhanced Anti-Microorganism Capability," and U.S. Patent Application No. 10/074,347, entitled "Electro-Kinetic Air Transporter

and Conditioner Device with Enhanced Housing Configuration and Enhanced Anti-Microorganism Capability," each of which is incorporated herein by reference.

[0072] FIG. 15 is an electrical block diagram showing an exemplary implementation of the high voltage source 340 the can be used to power the various embodiments of the present invention discussed above. An electrical power cord 1502 that plugs into a common electrical wall socket can be used to accept a nominal 110VAC. An electromagnetic interference (EMI) filter 1510 is placed across the incoming nominal 110VAC line to reduce and/or eliminate high frequencies generated by the various circuits. In embodiments including a germicidal lamp 1590, an electronic ballast 1512 is electrically connected to the germicidal lamp 1590 to regulate, or control, the flow of current through the lamp 1590. Electrical components such as the EMI Filter 1510 and electronic ballast 1512 are well known in the art and do not require a further description.

[0073] A DC Power Supply 1514, which is well known, is designed to receive the incoming nominal 110VAC and to output a first DC voltage (e.g., 160VDC). The first DC voltage (e.g., 160VDC) is shown as being stepped down through a resistor network to a second DC voltage (e.g., about 12VDC) that a micro-controller unit (MCU) 1530 can monitor without being damaged. The MCU 1530 can be, for example, a Motorola 68HC908 series micro-controller, available from Motorola. In accordance with an embodiment of the present invention, the MCU 1530 monitors the stepped down voltage (e.g., about 12VDC), which is labeled the AC voltage sense signal in FIG. 15, to determine if the AC line voltage is above or below the nominal 110VAC, and to sense changes in the AC line voltage. For example, if a nominal 110VAC increases by 10% to 121VAC, then the stepped down DC voltage will also increase by 10%. The MCU 1530 can sense this increase and then reduce the pulse width, duty cycle and/or frequency of the low voltage pulses it outputs to maintain the output

power of the high voltage source 340 to be the same as when the line voltage is at 110VAC. Conversely, when the line voltage drops, the MCU 1530 can sense this decrease and appropriately increase the pulse width, duty cycle and/or frequency of the low voltage pulses to maintain a constant output power. Such voltage adjustment features also enable the same unit to be used in different countries that have different nominal voltages than in the United States (e.g., in Japan the nominal AC voltage is 100VAC).

[0074] Output voltage potentials of the high voltage source 340 can be provided to the emitter array 310, the collector array 320 and/or the insulated driver array 330, depending upon which embodiment of the present invention discussed above is being practiced. The high voltage source 340 can be implemented in many ways. In the exemplary embodiment shown, the high voltage source 340 includes an electronic switch 1526, a step-up transformer 1516 and a voltage multiplier 1518. The primary side of the step-up transformer 1516 receives the first DC voltage (e.g., 160VDC) from the DC power supply. An electronic switch receives low voltage pulses (of perhaps 20 -25 KHz frequency) from the MCU 1530. Such a switch is shown as an insulated gate bipolar transistor (IGBT) 1526. The IGBT 1526, or other appropriate switch, couples the low voltage pulses from the MCU 1530 to the input winding of the step-up transformer 1516. The secondary winding of the transformer 1516 is coupled to the voltage multiplier 1518, which outputs high voltage pulses that can be provided to the arrays 310, 320 and/or 330, based on which embodiment is implemented. In general, the IGBT 1526 operates as an electronic on/off switch. Such a transistor is well known in the art and does not require a further description. When driven, the high voltage source 340 receives the low input DC voltage (e.g., 160VDC) from the DC power supply 1514 and the low

voltage pulses from the MCU 1530, and generates high voltage pulses of, for example, 10 KV peak-to-peak, with a repetition rate of, for example, about 20 to 25 KHz.

[0075] Referring back to the embodiment of FIG. 3, the voltage multiplier 1518 can output, for example, +4 KV to the emitter array 310, and about –6 KV to the collector array 320. In this embodiment, the insulated driver array 330 is grounded. Thus, in this example there is a 10 KV voltage potential difference between the emitter array 310 and the collector array 320, and a 6 KV voltage potential difference between the insulated driver array 330 and the collector array 320.

[0076] Referring back to the embodiment of FIG. 4, the voltage multiplier 1518 can output, for example, -10 KV to the collector array 320, while both the emitter array 310 and the insulated driver array 330 are grounded. In this example, there is a 10 KV voltage potential difference between the emitter array 310 and the collector array 320, and a 10 KV difference between the insulated driver array 330 and the collector array 320.

[0077] Referring back to the embodiment of FIG. 5, the voltage multiplier 1518 can output, for example, -10 KV to the collector array 320, and +5 KV to the insulated driver array 330. In this embodiment the emitter array 310 is grounded. Thus, in this example there is a 10 KV voltage potential difference between the emitter array 310 and the collector array 320, and a 15 KV difference between the insulated driver array 330 and the collector array 320.

[0078] These are just a few examples of the various voltages the can be provided for a few of the embodiments discussed above. It is within the scope of the present invention for the voltage multiplier 1518 to produce greater or smaller voltages. The high voltage pulses can have a duty cycle of, for example, about 10%-15%, but may have other duty cycles, including a 100% duty cycle.

[0079] The MCU 1530 can receive an indication of whether the control dial 1410 is set to the LOW, MEDIUM or HIGH airflow setting. The MCU 1530 controls the pulse width, duty cycle and/or frequency of the low voltage pulse signal provided to switch 1526, to thereby control the airflow output, based on the setting of the control dial 1410. To increase the airflow output, the MCU 1530 can increase the pulse width, frequency and/or duty cycle . Conversely, to decrease the airflow output rate, the MCU 1530 can reduce the pulse width, frequency and/or duty cycle. In accordance with an embodiment, the low voltage pulse signal (provided from the MCU 1530 to the high voltage source 340) can have a fixed pulse width, frequency and duty cycle for the LOW setting, another fixed pulse width, frequency and duty cycle for the MEDIUM setting, and a further fixed pulse width, frequency and duty cycle for the HIGH setting. However, depending on the setting of the control dial 1410, the above described embodiment may produce too much ozone (e.g., at the HIGH setting) or too little airflow output (e.g., at the LOW setting). According, a more elegant solution, described below, can be used.

[0080] In accordance with an embodiment , the low voltage pulse signal created by the MCU 1530 modulates between a "high" airflow signal and a "low" airflow signal, with the control dial setting specifying the durations of the "high" airflow signal and/or the "low" airflow signal. This will produce an acceptable airflow output, while limiting ozone production to acceptable levels, regardless of whether the control dial 1410 is set to HIGH, MEDIUM or LOW. For example, the "high" airflow signal can have a pulse width of 5 microseconds and a period of 40 microseconds (i.e., a 12.5% duty cycle), and the "low" airflow signal can have a pulse width of 4 microseconds and a period of 40 microseconds (i.e., a 10% duty cycle). When the control dial 1410 is set to HIGH, the MCU 1530 outputs a low voltage pulse signal that modulates between the "low" airflow signal and

the "high" airflow signal, with, for example, the "high" airflow signal being output for 2.0 seconds, followed by the "low" airflow signal being output for 8.0 second. When the control dial 1410 is set to MEDIUM, the "low" airflow signal can be increased to, for example, 16 seconds (e.g., the low voltage pulse signal will include the "high" airflow signal for 2.0 seconds, followed by the "low" airflow signal for 16 seconds). When the control dial 1410 is set to LOW, the "low" airflow signal can be further increased to, for example, 24 seconds (e.g., the low voltage pulse signal will include a "high" airflow signal for 2.0 seconds, followed by the "low" airflow signal for 24 seconds). Alternatively, or additionally, the frequency of the low voltage pulse signal (used to drive the transformer 1516) can be adjusted to distinguish between the LOW, MEDIUM and HIGH settings. These are just a few examples of how air flow can be controlled based on a control dial setting.

[0081] In practice, an electro-kinetic transporter-conditioner unit is placed in a room and connected to an appropriate source of operating potential, typically 110 VAC. The energized electro-kinetic transporter conditioner emits ionized air and small amounts of ozone via outlet vents 1460. The airflow is indeed electro-kinetically produced, in that there are no intentionally moving parts within unit. (Some mechanical vibration may occur within the electrodes). Additionally, because particles are collected on the collector electrodes 322, the air in the room is cleaned. It would also be possible, if desired, to further increase airflow by adding a fan. Even with a fan, the insulated driver electrode(s) 332 can be used to increase particle collecting efficiency by allowing the electrical field between the driver electrode(s) and collector electrodes to be increased beyond what would be allowable without the insulation.

[0082] Experiments have shown that insulating the driver electrodes have allowed the voltage potential between the collectors and driver(s) to be increased, thereby increasing particle collection

efficiency. These experiments were performed using a test system including a single grounded emitter wire 312, a pair of collector electrodes 322, and a single driver electrode. In a first test it was determined that the voltage potential between the collector electrodes 322 and a non-insulated driver electrode (located between the collector electrodes 322) should be no more than 9.4 KV, with any higher voltage potential being very susceptible to arcing between the collectors and driver. Specifically, the collector electrodes 322 were placed at –15 KV, the non-insulated driver was placed at –5.6 KV, and the emitter wire 312 was grounded. The particle collecting efficiency was then measured for various particle sizes ranging. The results are shown as line 1602 in the graph of FIG. 16. As shown in FIG. 16, the collecting efficiency for small particles of about 0.3 μm was only about 50%.

[0083] The non-insulated driver electrode was then replaced with an insulated driver electrode 332 having the same dimensions. It was then determined that the voltage potential difference between the collector electrode 322 and the insulated driver electrode 332 could be increased to 15 KV without being highly susceptible to arcing between the collectors 322 and insulated driver 332. By increasing the voltage potential difference from 9.4 KV to 15 KV the electric field between the collector and drivers increased from about 750 V/mm to about 1200 V/mm. Specifically, the collector electrodes 322 were placed at 15 KV and the emitter electrode 312 and the insulated driver electrode 332 were both grounded. The results are shown as line 1604 in the graph of FIG. 16. As shown in FIG. 16, the collecting efficiency for small particles of about 0.3 μm increased to about 60%.

[0084] Experiments have also shown that particle collecting efficiency can be further increased by increasing the width (the dimension in the downstream direction) of the collector electrodes 322.

However, this would also increase the cost and weight of a system, and thus, is a design tradeoff. But for given width of collector electrodes and driver electrodes, insulating the drivers will allow the electric field between the collectors and drivers to be increased (as compared to if the drivers were not insulated), thereby increasing particle collection efficiency.

[0085] The foregoing descriptions of the preferred embodiments of the present invention have been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to the practitioner skilled in the art. Modifications and variations may be made to the disclosed embodiments without departing from the subject and spirit of the invention as defined by the following claims. Embodiments were chosen and described in order to best describe the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention, the various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.